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AUTHOR Lee, Joohi; Meadows, Mikki; Lee, Joo Ok

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ABSTRACT

Noting that children's early mathematics experience is a significant factor in their future mathematics outcomes and attitudes, this paper discusses the importance of developmentally appropriate practices in mathematics instruction for young children and explores how teachers' pedagogical content knowledge determines their teaching practices in mathematics. The paper explains that pedagogical content knowledge refers to the integration of pedagogical, or teaching, knowledge and content knowledge; it refers to the way teachers transfer their subject matter knowledge into an understanding of particular topics, problems, or issues in order to present information to diverse learners' varying abilities and interests. The paper discusses four elements of pedagogical content knowledge of mathematics in early childhood settings: (1) teachers' understanding of mathematics content; (2) teachers' understanding of children's understanding of mathematics content; (3) teachers' understanding of children's mathematics problem-solving process; and (4) teachers' understanding of the organization of the mathematics environment based on children's understanding of mathematics content and the process of children's understanding of mathematics. (Contains 19 references.) (EV)

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What Causes Teachers to Implement High-Quality Mathematics Education More Frequently: Focusing on Teachers' Pedagogical Content Knowledge

1,928 words plus references

Submitted by

Joohi Lee
Doctoral Candidate
Elementary and Early Childhood Education
Indiana State University
Terre Haute, IN 47807
Telephone: 812-237-2853
Fax: 812-237-8202
lecj6@coral.indstate.edu

Dr. Meadows, Mikki
Instructor
Family and Consumer Science
Eastern Illinois University
Charleston, IL 61920
cfmlm@eiu.edu
Telephone: 217-348-0979
Fax: 217-581-6090

Joo Ok Lee
Doctoral Student
Early Childhood Education
Duksung Women's University
Ssang-Moon-Dong, Seoul
Korea (ROK)
hadasa55@yahoo.co.kr
Telephone: 31-941-1532
Fax: 31-944-7607

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American students' tendency toward poor performance in mathematics has been revealed in several international series of assessments such as the Third International Mathematics and Science Study (TIMSS) and the International Assessment of Educational Progress. Results of these assessments have challenged educators, policy makers, and parents concerned with improving students' mathematics achievement. Both the National Association for the Education of Young Children and the National Council for Teachers of Mathematics agree in regard to the importance of early mathematics experiences, affirming their impact on children's later mathematics achievement and attitudes toward mathematics (NAEYC & NCTM, 2002).

Children's early mathematics experience has been highlighted in many studies as a significant factor in determining their future mathematics outcomes and attitudes toward mathematics. For this reason, teacher educators and policy makers are concerned with how to assist preservice teachers in implementing high-quality mathematics instruction in their prospective classrooms.

Traditional mathematics instruction has favored focusing on mastering specific mathematical skills using formal and direct instruction. However, criticisms of these traditional methods of teaching mathematics have occurred. In fact, contemporary experts cite the use of developmentally appropriate mathematics instruction for young children as a viable alternative to traditional instruction (Burts, Hart, Charlesworth, DeWolf, Ray, Manuel & Fleege, 1993; Cognition and Technology Group at Vanderbilt University, 1993; Sherman & Mueller, 1996).

In general, developmentally appropriate practice is strongly recommended in early childhood education settings to provide children with high-quality programs (Dunn & Kontos, 1997). Unfortunately, few early childhood education classrooms have been observed to implement developmentally appropriate practice. Studies reported that only about one-third to one-fifth of programs associated with play-based and child-initiated programs were found to use developmentally appropriate practice (Bryant, Clifford & Peisner, 1991; Dunn & Kontos, 1997; Oakes & Caruso, 1990).

Many early childhood educators have argued that formal and direct instruction of mathematics should be avoided while showing support for the practice of developmentally appropriate mathematics (NCTM, 2000). They state that developmentally inappropriate curriculum emphasizing rote and drill-based learning could create negative attitudes toward mathematics. Most empirical data related to mathematics education has found that practices that are not consistently developmentally appropriate are associated with poorer mathematics outcomes and lower conduct and work-study habits (Charlesworth, 1998).

In contrast, mathematics instruction that utilizes developmentally appropriate practice has been found to be beneficial in children's later mathematics achievement and their attitudes toward mathematics (Burts et al., 1993; Charelsworth, 1998; Charlesworth et al., 1993). These reports cause early childhood educators and teacher trainers to consider what makes teachers able to identify developmentally appropriate mathematics practices and proceed to implement them more frequently with children.

Studies have revealed that teachers' pedagogical content knowledge of mathematics is a significant determinant of their teaching practices in mathematics. Some scholars have

even claimed the lack of teachers' pedagogical content knowledge in mathematics has resulted in American students' lower academic outcomes in mathematics (Graeber, 1999; Leinhardt, 1986). The term "pedagogical content knowledge" is comparatively new. Shuman (1987) officially used the term at a Presidential Address during the annual meeting of the American Educational Research Association in 1985. Pedagogical content knowledge refers to the integration of pedagogical knowledge and content knowledge. Pedagogical content knowledge refers to the way teachers transfer their subject matter knowledge into an understanding of particular topics, problems, or issues in order to present information to diverse learners varying abilities and interests (Fuller, 1996). It also includes an understanding of the content and an understanding of effective organization in order to transfer certain subject content matters (Shulman, 1987).

How teachers link their knowledge to their teaching performance, frequently referred to as "pedagogical content knowledge", is critically important for children when they are learning mathematics (Anders, 1995; Eylon & Reif, 1984; Leinhardt, 1986). Research has shown both pedagogical knowledge and content knowledge are critical elements of effective teaching (Anders, 1995; Eylon & Reif, 1984; Leinhardt, 1986). Some scholars have even claimed the lack of teachers' pedagogical content knowledge in mathematics resulted in American students' lower academic outcomes in mathematics (Graeber, 1999; Leinhardt, 1986).

Pedagogical content knowledge consists of two major components--content knowledge and pedagogical knowledge (Shulman, 1987; Gudmundsdottir, 1990). Both types of knowledge have been emphasized as essential for quality teaching. Quinn (1997) emphasized that teachers' content knowledge of the subject is necessary and serves as a

fundamental element for quality teaching. Shulman (1986) agreed that what teachers know is one of the most important predictors of what is done in classrooms. In addition, teachers' lack of knowledge in certain subjects causes them to avoid teaching them. For this reason, it is essential for teachers to have deep content-wise knowledge of mathematics.

Some of the empirical data reported pedagogical knowledge as a more critical element in teaching than content knowledge. For example, early childhood teachers may have subject matter content knowledge of mathematics; however, it might not be always represented in their teaching. Teachers or teacher candidates usually have rote knowledge of certain mathematics formulas, but many differences were demonstrated among teachers or teacher candidates when they implement it in their teaching. Teachers may have proficient content knowledge of the mathematics that young children need to know, but that doesn't mean teachers implement mathematics education for young children in a manner that is appropriate for their developmental needs.

Kennedy (1998) provides an example that supports the importance of pedagogical knowledge: a person may know the way to the grocery store but be unable to give directions to others. In effect, this person may have deep conceptual understanding and yet have difficulty outlining it to others. Kennedy stated, " ...teachers' and teacher candidates' representations of certain mathematics ideas found that the ability to generate representations is indeed quite different from recitational knowledge" (Kennedy, 1998, p. 237). However, teachers still must have deep subject matter content knowledge. According to the joint statement on "Early Childhood Mathematics: Promoting Good Beginnings" proposed by NAEYC and NCTM (2002), teachers should have both

mathematics content knowledge--"knowledge of the mathematical content and concepts most relevant for young children" (NAEYC & NCTM, 2002, p.11)--and pedagogical knowledge, e.g., knowledge of children learning process in mathematics, efficient ways to teach, or skills to assess children's learning mathematics.

Pedagogical content knowledge of mathematics in early childhood settings involves the following elements: 1) teachers' understanding of mathematics contents; 2) teachers' understanding of children' understanding of mathematics contents; 3) teachers' understanding of children's understanding process in mathematics, and; 4) teachers' understanding of the organization of mathematics education based on children's understanding of mathematics contents and the process of children' understanding of mathematics. These elements are discussed in detail below.

1) Teachers' understanding of mathematics content knowledge

To implement high-quality mathematics practice, teachers should have an understanding of mathematics content knowledge. NCTM (2000) proposed five content standards related to what pre-K through grade 12 students should learn in mathematics: number and operations, algebra, geometry, measurement, and data analysis and probability. Many states also provide teachers with content standards that describe what kindergartners or preschoolers should know related to mathematics, e.g., California, Colorado, Kansas, New Jersey, and Utah. Before early childhood teachers teach or implement mathematics education in their classroom, they should self-assess their competency in understanding mathematical content. Teachers' lack of understanding of certain areas of mathematics may cause them to avoid incorporating specific topics into

their teaching. To implement high-quality mathematics education, teachers should have proficient mathematics content knowledge.

2) Teachers' understanding of what children already know in mathematics

To implement high-quality mathematics education, early childhood teachers should understand what their children already know about mathematics. Children's everyday lives are closely related to mathematics. They see mathematics everywhere they go, e.g., different numbers, patterns, shapes, and sizes. Children have considerable informal mathematical knowledge even before they go to school. To implement high-quality mathematics education, teachers should formally and informally assess the ability children have through observation of their play, assessment of classroom work, or interviews with parents. These assessments are all effective methods to enable teachers to understand what children already know about mathematics.

3) Teachers' understanding of children's mathematics problem solving process

Early childhood teachers should understand how children process mathematical concepts associated with comparing numbers, quantities, or volume. For example, very young children use visual perception more often than rational mathematical methodology--one-to-one correspondence or counting strategy--when they are asked to decide the size of sets of materials. Once children are capable of using mathematical methodology --matching items or counting numbers--they begin to use mathematical methodology more frequently to compare number sets. Children have specific ways of solving mathematics problems based on their mathematics conceptual knowledge and cognitive developmental status. These strategies change as children's cognition undergoes the developmental process and their mathematics knowledge grows. To implement high-

quality mathematics education, early childhood teachers should understand how children process mathematics problems.

4) Teachers' understanding of organization of mathematics environments

Early childhood teachers should have an understanding of how to organize the mathematics environments in their school. Above all, early childhood teachers should consider providing interdisciplinary mathematics education, which incorporates mathematics with other subjects. Not only does mathematics occur in the mathematics center, but it also occurs everywhere children go: the language center, art center, housekeeping center, block center, or playground for instance. Teachers may question themselves when they set up all classroom activities: Do I expect children to do math in each center? What math contents could be incorporated in each center? How do I encourage children to do math in each center? These questions should be answered by teachers before implementing classroom activities.

When early childhood teachers plan mathematics education, they should also incorporate real-life mathematics activities. Let's assume that teachers want to implement mathematics education related to fractions in their classroom. NCTM (2000) states, "In prekindergarten through grade 2 all students should understand and represent commonly used fractions..." (p. 392). Children already possess mathematics content knowledge of fractions, such as sharing things with their peers or siblings. One efficient way to do fractions with young children is by sharing food or toys. Teachers may encourage children to explore how to equally share pizza or cake with their peers. This will provide young children additional conceptual knowledge of fractions. Teachers may also integrate the basic concept of fractions after children have had opportunities to examine

fractions within their own experiences. Children learn mathematics effectively within meaningful context (Breadekamp & Copple, 1997) which originates from their real-life experiences. To implement high-quality mathematics education in an early childhood classroom, teachers should be able to incorporate children's real-life with mathematics while connecting children's informal knowledge and formal knowledge of mathematics.

As indicated above, early mathematics experience is very important for children's later mathematics achievement and fostering positive attitudes toward mathematics. NAYEC and NCTM (2002) reemphasized the importance of early mathematics education, considering it a crucial factor for children's later mathematics learning. To increase children's competence in mathematics, early childhood teachers should continue reflecting on their pedagogy and how to implement high-quality mathematics education in classrooms. Teachers should recognize that mathematics concepts can be implemented in early childhood classroom settings if teachers have deep content knowledge related to mathematics and they are able to transfer that knowledge to children in an understandable manner.

Teacher educators, at the same time, should consider the fact that preservice teachers have qualified knowledge. NAEYC and NCTM (2002) supported the idea that teacher educators should prepare preservice teachers to have mathematics knowledge and knowledge of effective methods that can be used to teach mathematics. Thus, teacher educators should ensure that preservice teachers have qualified pedagogical content knowledge of mathematics in order to be ready to integrate high-quality teaching in their prospective classrooms.

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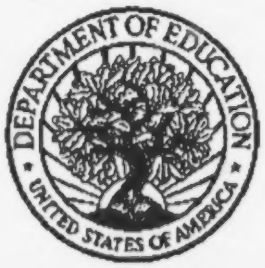

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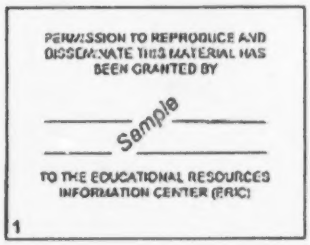
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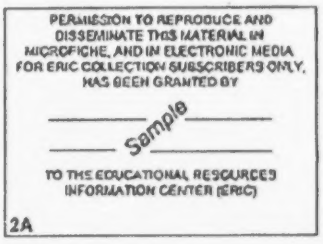
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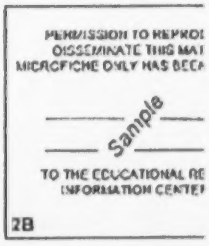

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Signature: Joohi Lee

Printed Name: Joohi Lee

Position/Title: Doctoral Candidate

Organization: Indiana State University

Address: Elementary and Early Childhood Edu, Indiana State Uni, Terre Haute IN 47809

Telephone Number: 812-237-2853

FAX: 812-237-8202

E-mail address: lee;6@coral.indstate.edu

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